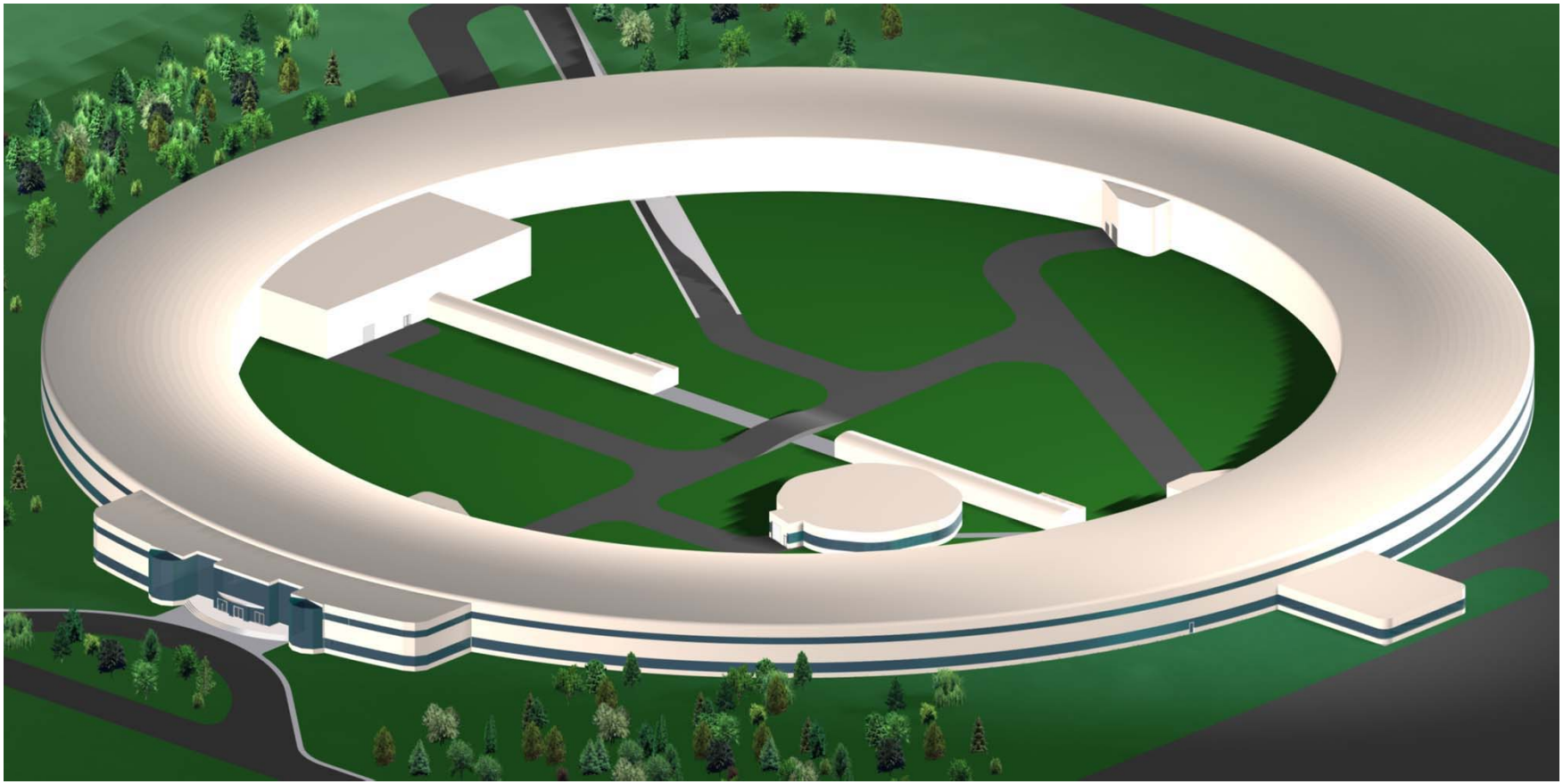
NSLS-II



Steve Dierker
NSLS-II Workshop
Associate Laboratory Director for Light Sources and Chairman, NSLS
March 15, 2004

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U.S. DEPARTMENT OF ENERGY

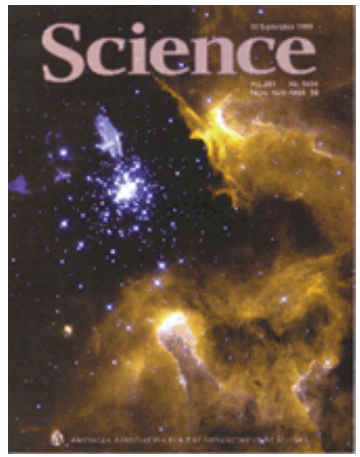
BROOKHAVEN NATIONAL LABORATORY
BROOKHAVEN SCIENCE ASSOCIATES

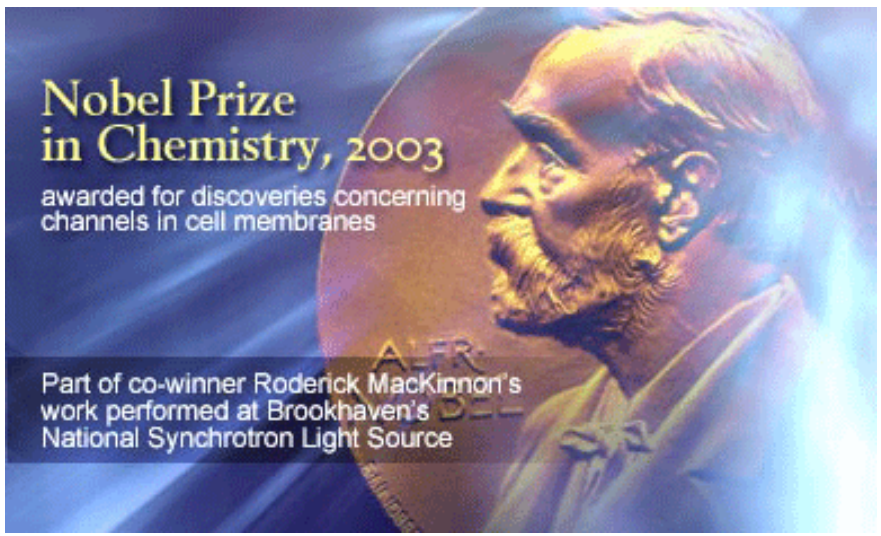
NSLS: Outstanding Scientific Productivity

Many Scientific Programs Highly Productive & High Impact

- ~ 800 publications per year
- ~ 130 publications/year in premier journals

(PRL, Science, Nature, Cell, EMBO J., Nature Str. Bio., Proc. Nat. Acad. Sci, Structure, APL)





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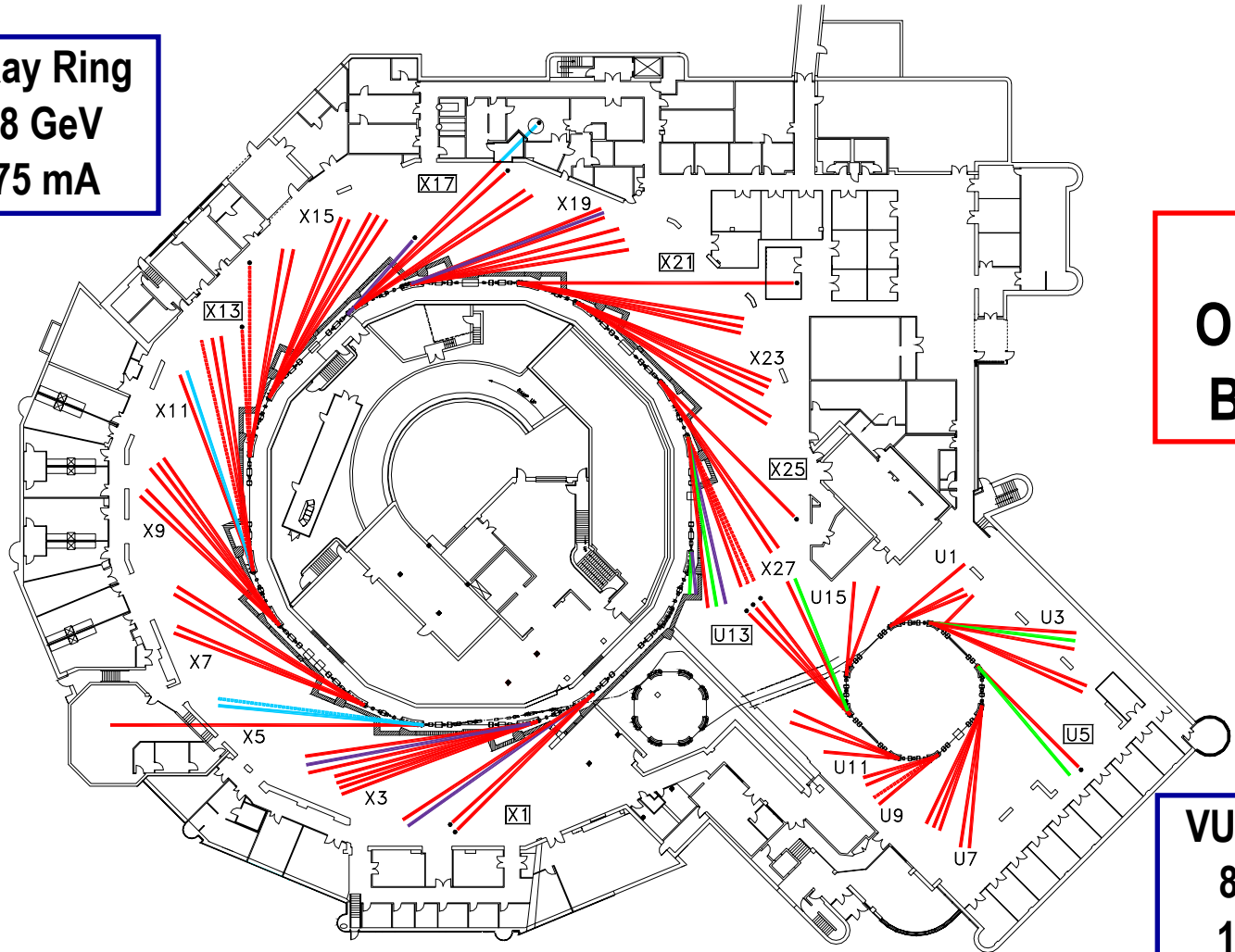
Present NSLS

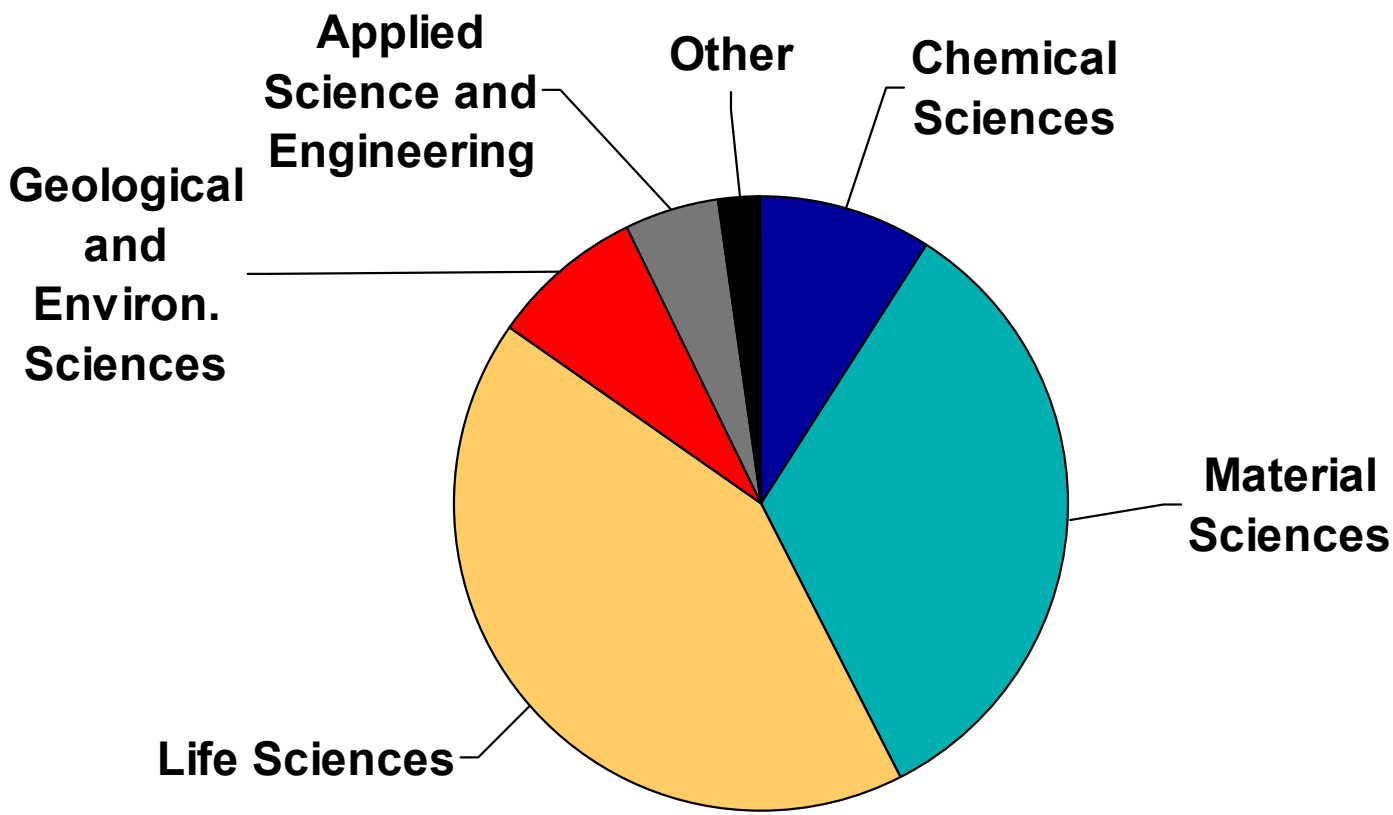
X-Ray Ring
2.8 GeV
275 mA



80
Operational
Beamlines

VUV/IR Ring
800 MeV
1000 mA

Diverse Science: Users by Field of Research

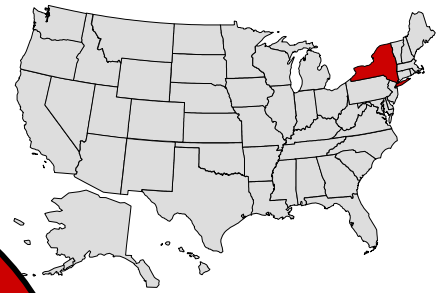


- Largest groups are materials and life sciences
- Strongest growth in life sciences

National & Regional Resource

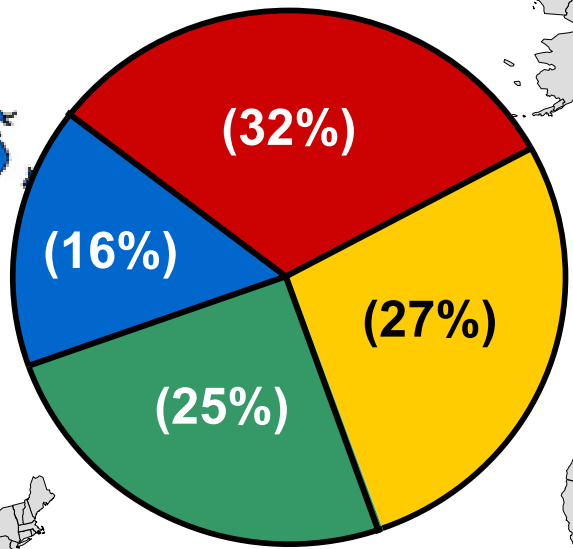
2400 Users/year (> 400 academic, industrial, government institutions)

International

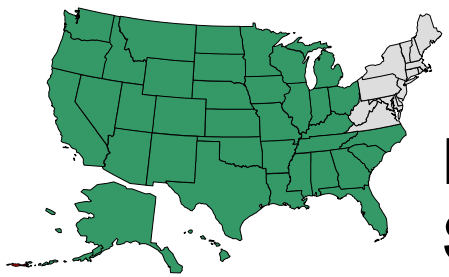


New York

Central to BNL programs



Other Northeast States

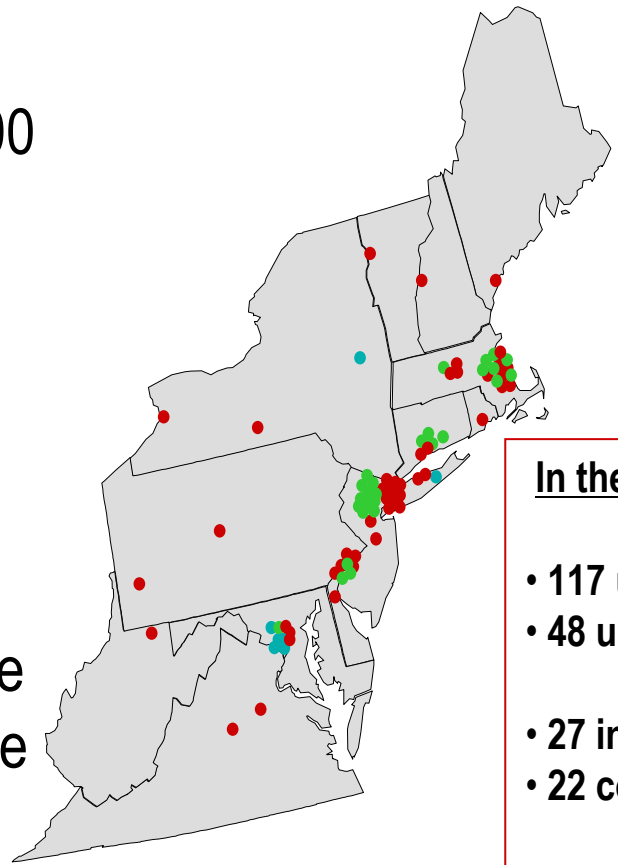


Non-Northeast States

Industry: IBM, ExxonMobil, Lucent, pharmaceuticals

Northeast Macromolecular Crystallography Users

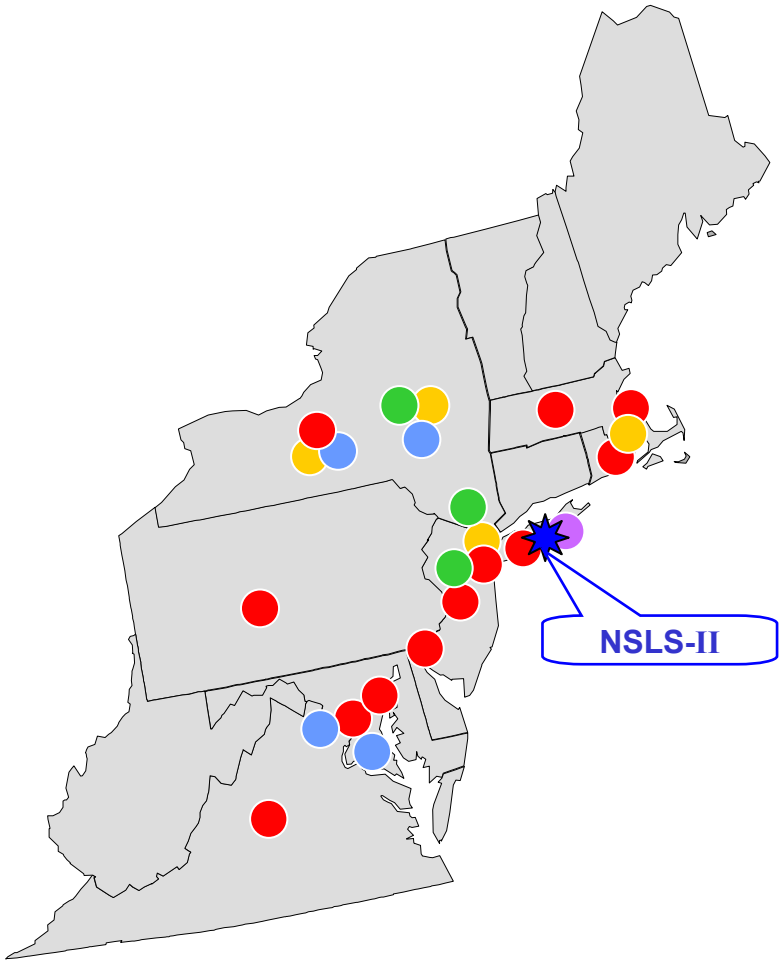
- 40% of the nation's users are from the Northeast region, spanning ~100 institutions (according to 2002 BioSync report)
- It is critical for users working on difficult projects to collect data at a nearby facility
- NSLS is well-positioned to serve the needs of the Nation, in particular the Northeast user community



In the East / Northeast:

- 117 university PIs
- 48 universities
- 27 industrial PIs
- 22 companies
- 32 government PIs
- 7 institutions

Northeast Nanoscience Users



- 1 DOE BNL Center for Functional Nanomaterials
- 4 NSF Nanoscale Science and Engineering Centers
- 12 NSF Materials Research Science & Engineering Centers (MRSECs) with Nanoscience Interdisciplinary Research Groups (IRGs)
- 4 Other University & Government Nanocenters
- 3 Industrial Nanoscience Efforts

5-10 Year Vision: Continue as Vital Resource in Northeast

- Beamlines and Endstations are being upgraded
- Scientific and user support staff are being added
- Current Initiatives:
  - Macromolecular Crystallography – X25 upgrade, new X29 beamline
  - Nanoscience – new X-ray Microprobe, LEEM/PEEM, SAXS beamlines
  - Biomedical Imaging – new full-field X-ray microscope
  - Detector development program

National Synchrotron Light Source

- First Dedicated Second Generation Synchrotron
  and only remaining second generation DOE synchrotron!
- Designed in the 1970's
- Operating Since 1982
- Continually updated over the years
  - Brightness has improved more than 100,000 fold
- *However*
  - The brightness has reached its theoretical limit
  - Only a small number of insertion devices are possible
- Restricted capabilities of present NSLS are increasingly limiting the productivity and impact of its large user community

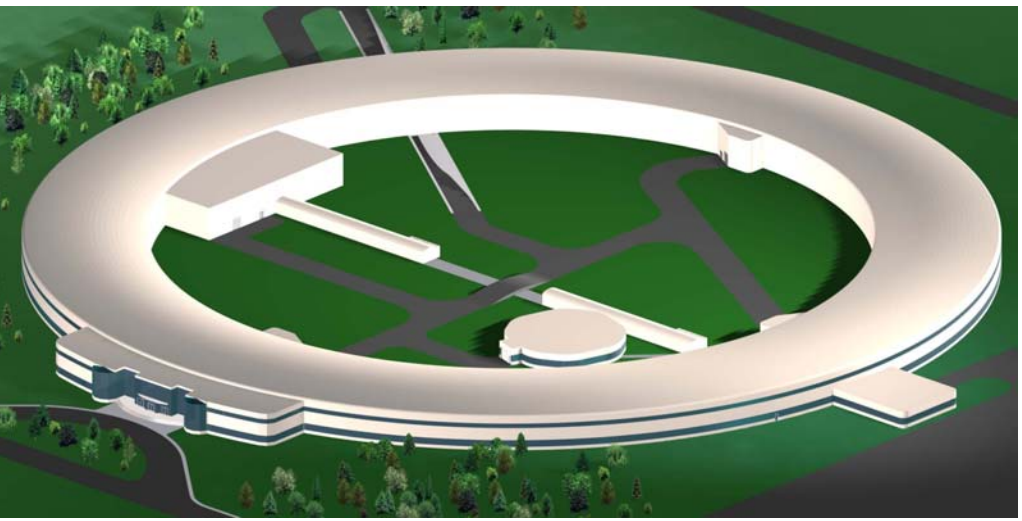
10+ Year Vision: Enable Grand Challenge Science by Providing World Leading Capabilities

What science will users do in 10+ years and what do they need to do it?

- Soft Matter & Biomaterials Workshop – April '02
- 8 Workshops at NSLS Users Meeting – May '02
- Ultra-high Resolution X-ray Spectroscopy Workshop – September '02
- Low Energy Electrodynamics in Solids Conference – October '02
- Microbeam Diffraction Workshop – January '03
- 6 Workshops at NSLS Users Meeting– May '03
- Scientific Opportunities in Macromolecular Crystallography at NSLS-II – July ' 03
- NSLS-II Environmental Science – August '03
- Strongly Correlated Electrons: NSLS-II and the Future – August '03
- Scientific Opportunities in Soft Matter and Biophysics at NSLS-II – September '03
- Biomedical Imaging at NSLS-II – September ' 03
- Nanoscience and NSLS-II – October '03
- **Workshop for NSLS-II – March '04**

NSLS-II: Ultra-high Brightness Medium Energy Third Generation Storage Ring and IR Ring

Highly Optimized X-ray Storage Ring



Dedicated Enhanced Infrared Ring

X-ray Ring

- 3 GeV, 500 mA, Top-off Injection
- Circumference 620 m
- 24 Cell, Triple Bend Achromat
- 21 Insertion Device Straight Sections (7 m)
- 24 Bending Magnet Ports
- Ultra-Low Emittance (ε_x, ε_y) 1.5, 0.008 nm
  (Diffraction limited in vertical at 10 keV)
- Brightness ~ 10^{21} p/s/0.1%bw/mm^2/mrad^2
- Flux ~ 10^{16} p/s/0.1%bw
- Beam Size (σ_x, σ_y) 84.6, 4.3 μm
- Beam Divergence (σ_x', σ_y') 18.2, 1.8 μrad
- Pulse Length (rms) 11 psec
- Exceptional intensity and position stability
- Upgradeable to ERL operation in future

Infrared Ring

- 800 MeV, 1000 mA, Top-off Injection

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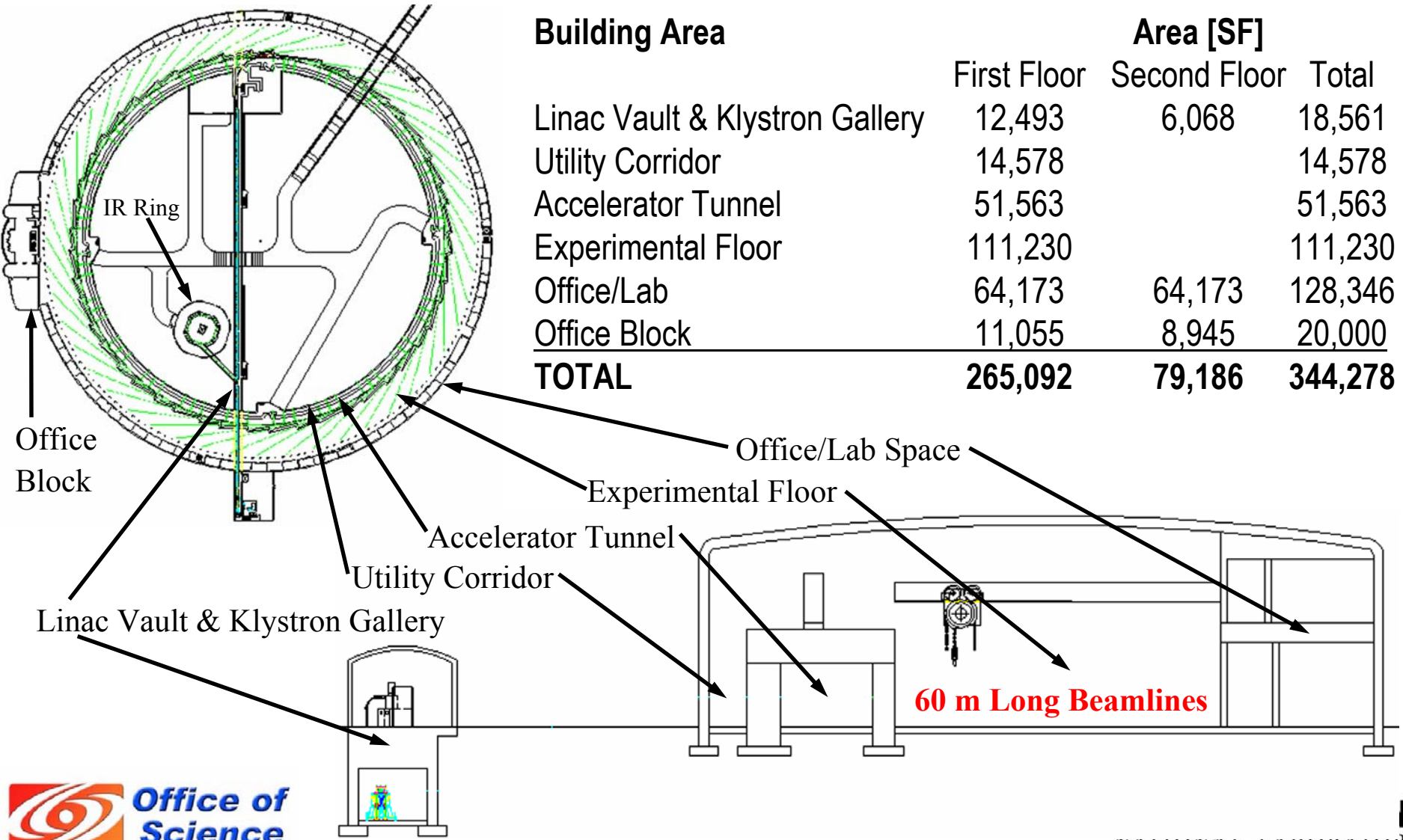
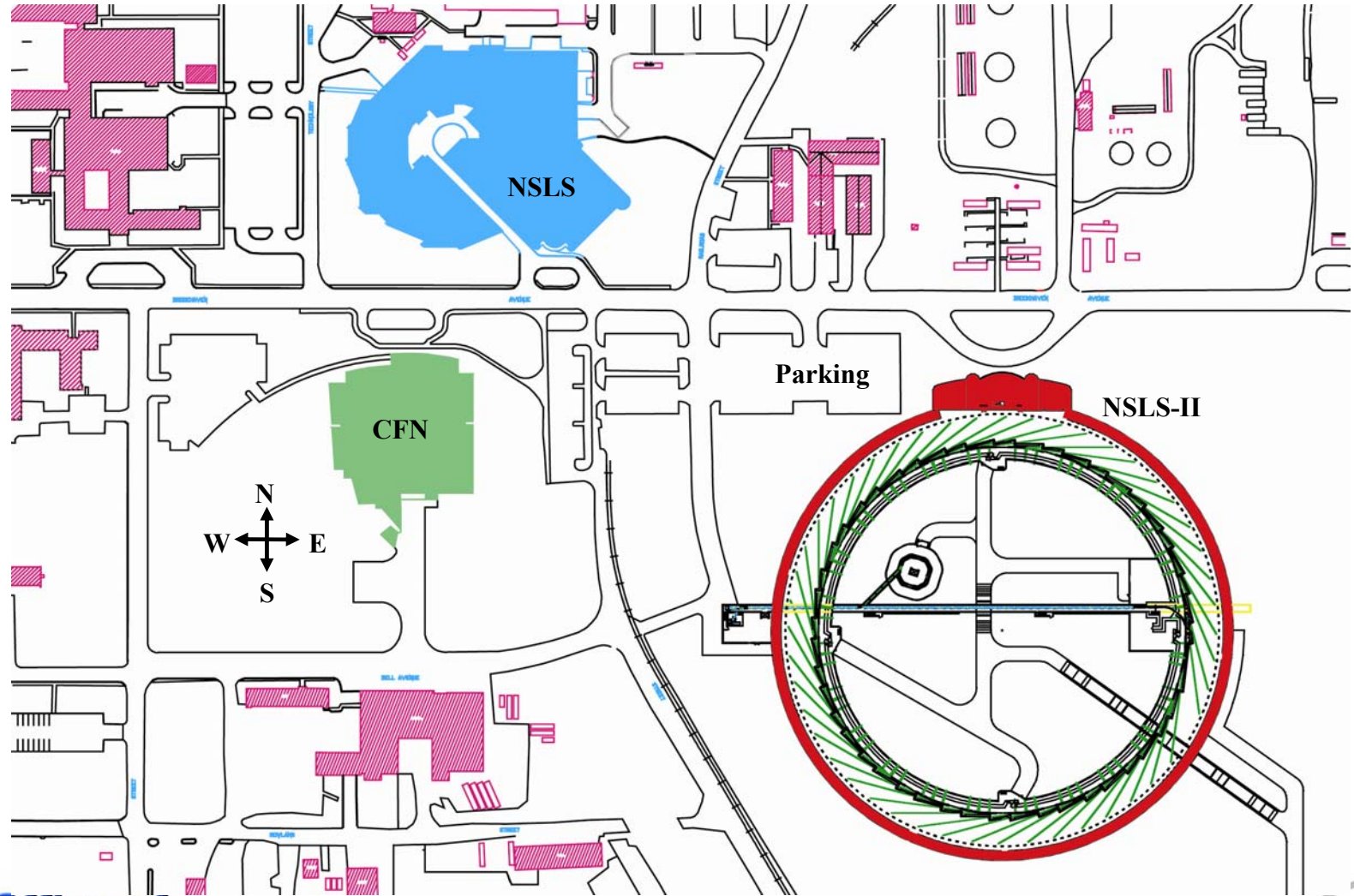
Facility Layout

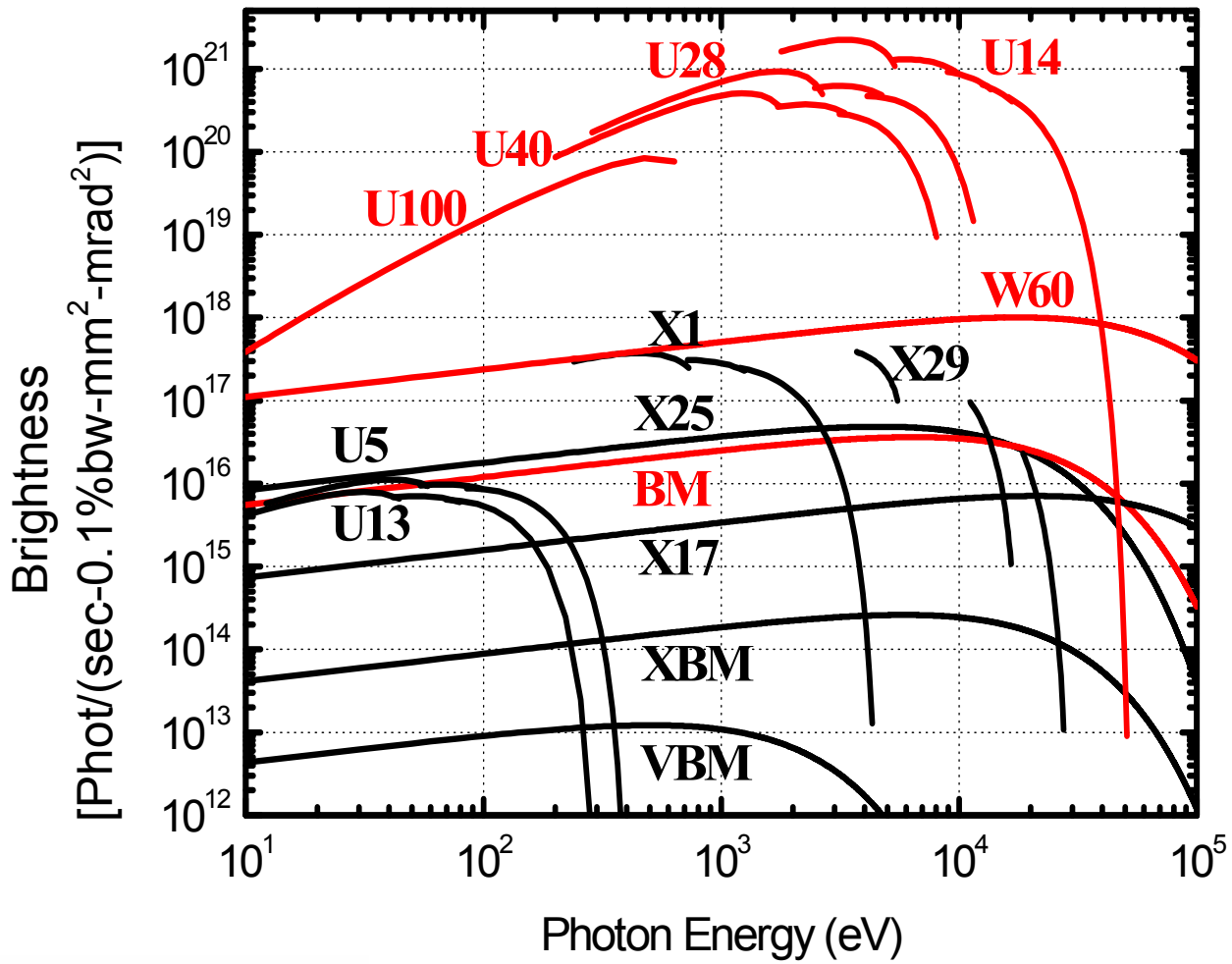
Building Area	Area [SF]		
	First Floor	Second Floor	Total
Linac Vault & Klystron Gallery	12,493	6,068	18,561
Utility Corridor	14,578		14,578
Accelerator Tunnel	51,563		51,563
Experimental Floor	111,230		111,230
Office/Lab	64,173	64,173	128,346
Office Block	11,055	8,945	20,000
TOTAL	**265,092**	**79,186**	**344,278**



Siting



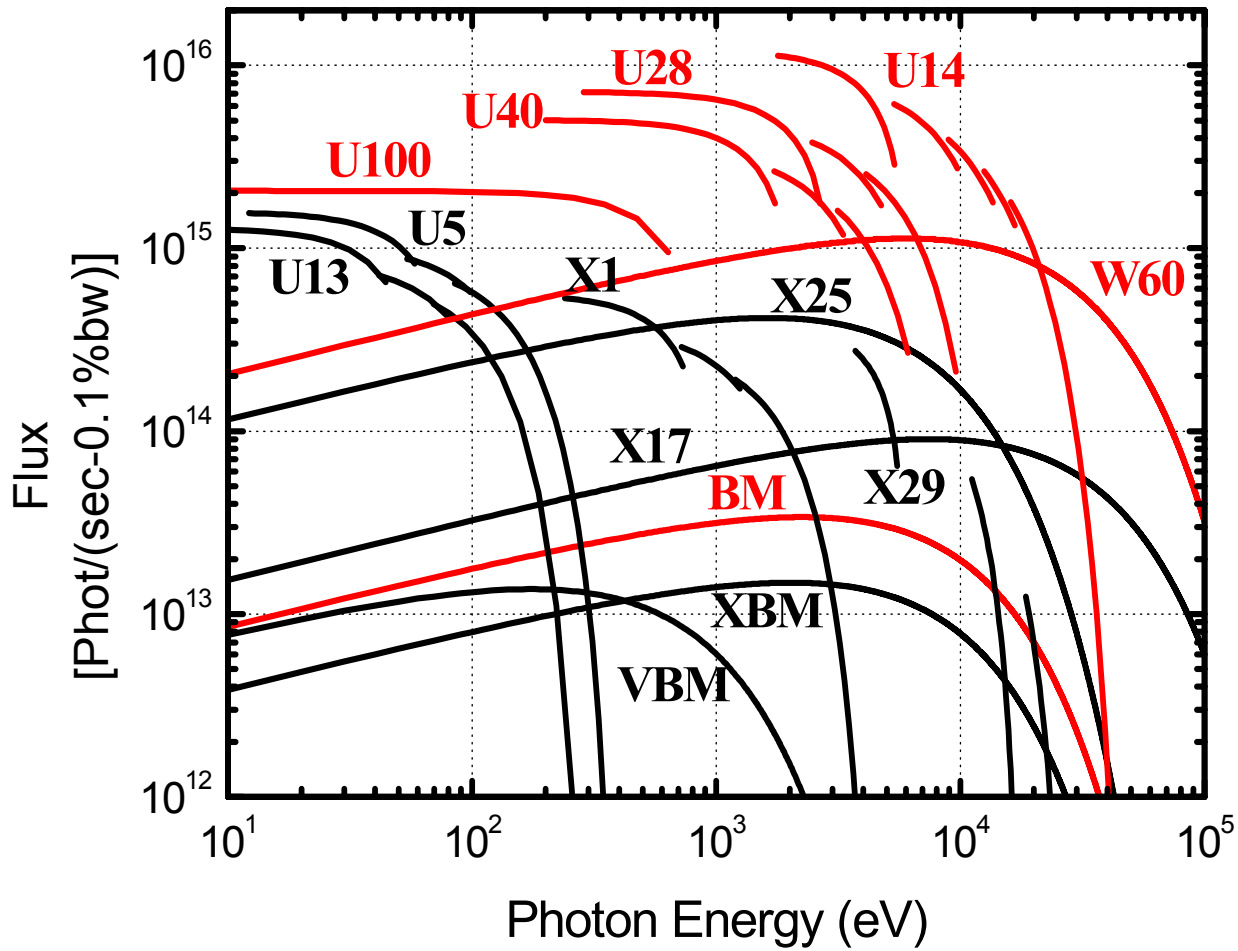
X-ray Brightness



NSLS	NSLS-II	Gain
X25	U14	3×10^4
BM	U14	5×10^6
BM	BM	10^2
X1	U40	10^3
U5	U100	10^2-10^3

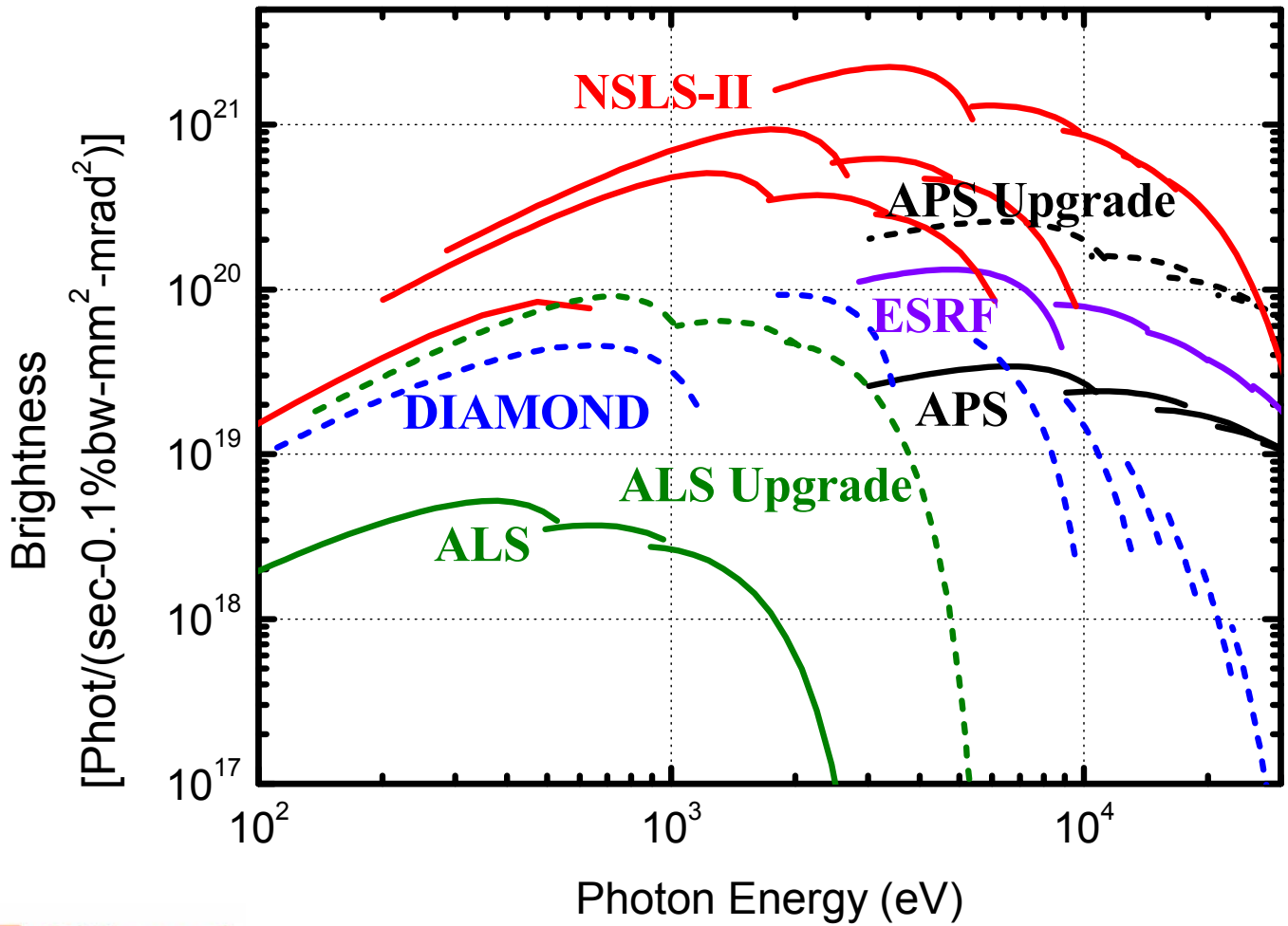
	NSLS	NSLS-II
# Und	5	21+
# BM	30	24

X-ray Flux



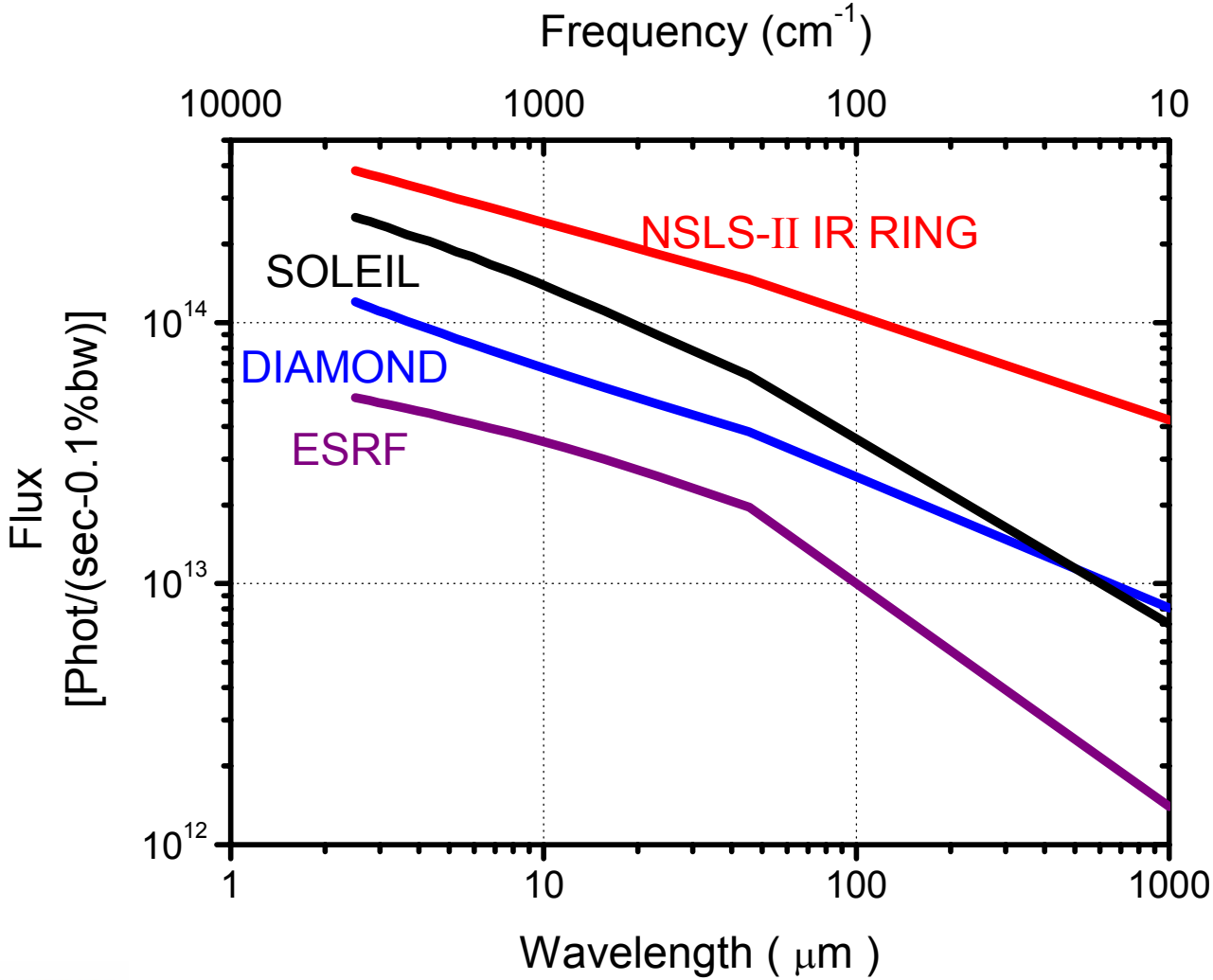
NSLS	NSLS-II	Gain
X25	U14	20
BM	U14	300
BM	BM	2
X1	U40	20
U5	U100	2-3

NSLS-II: World Leading Brightness

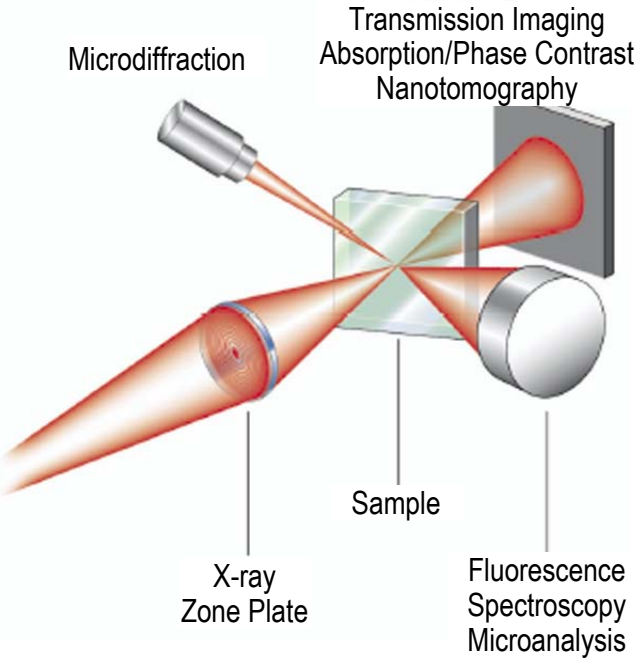


Current NSLS is off this chart at lower values

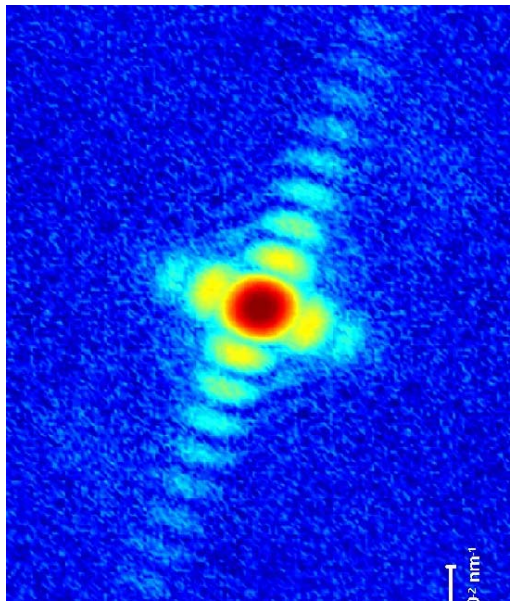
NSLS-II: World Leading Infrared Brightness and Flux



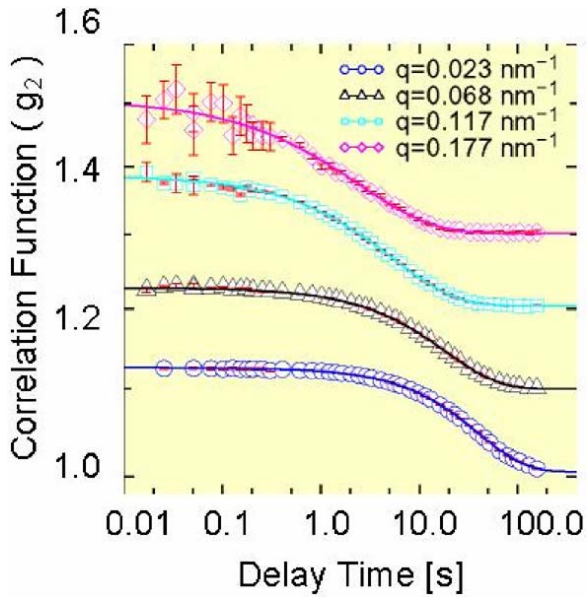
NSLS-II: New Capabilities



Nanoprobes
Structure, composition, magnetization w/
~ 10 nm resolution



Diffraction Imaging
Reconstructing Real Space Images w/
~ 2-3 nm resolution



X-ray Photon Correlation Spectroscopy
Studying Dynamics w/
~ 100 nsec resolution

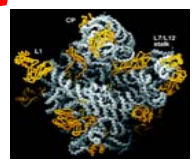
NSLS-II will provide the high brightness to make these possible

What is the Structure and Function of Molecular Machines?

Bending Magnet
B ~ 10^{15}

Protein (~100 Å)

High brightness is essential for projects with small crystals and large unit cells, such as large asymmetric complexes, particles like ribosomes, and membrane proteins.

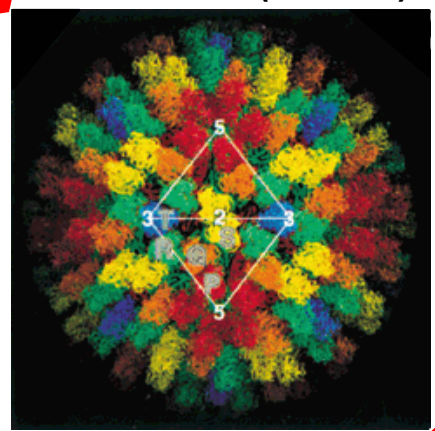


Ribosome (~250 Å)

Wiggler
B ~ 10^{17}

Virus (~750 Å)

Increased Brightness

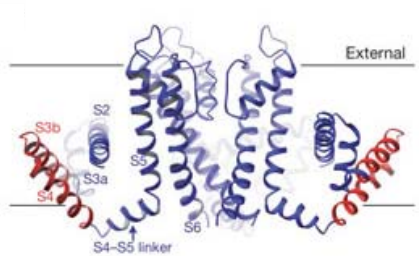


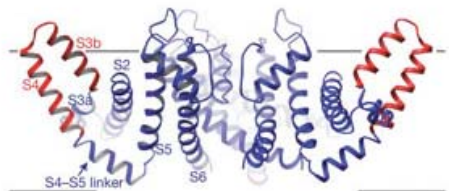
NSLS-II Undulator
B ~ 10^{21}

Molecular Machinery

NSLS-II will enable:

- **Large unit cells (> 1000 Å)**
- **Small crystals (~10 µm)**
- **High resolution (< 1.0 Å)**





Ion Channel Membrane Protein

Structural Genomics
Genomes to Life

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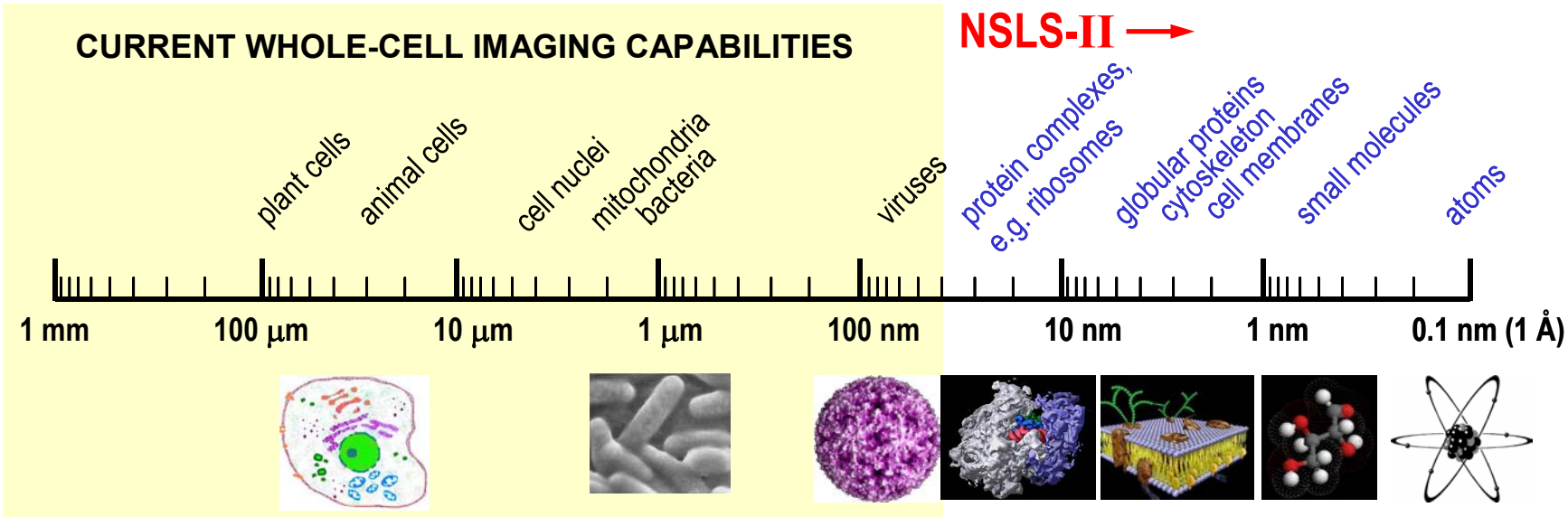
What is the Structure and Function of Molecular Machines?

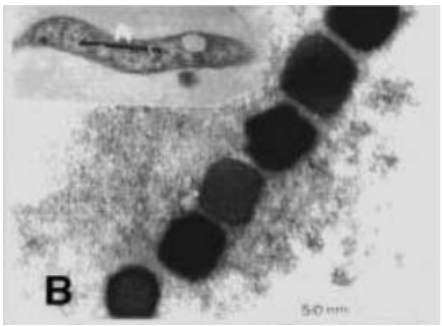
Biological Imaging will help define the interactions between proteins and other components in the complex interacting networks of living cells



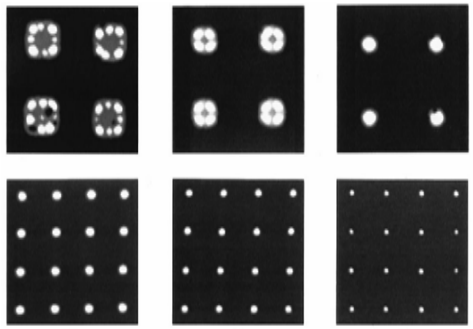
NSLS-II will enable:

- **Spectromicroscopy and imaging with <10 nm resolution**
- **Diffraction limited high brightness from mid- to near- IR**

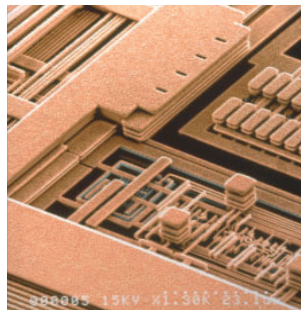
What are the Physical, Chemical, and Electronic Properties of Materials on Nanometer Length Scales?



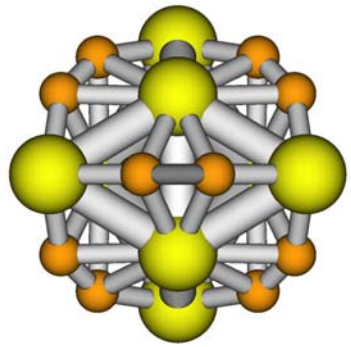
Biomaterials



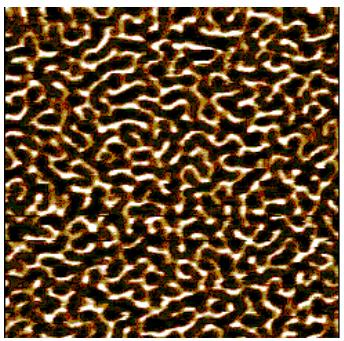
Quantum Dots



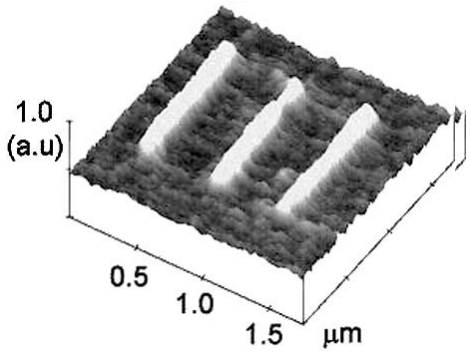
Electronic Devices



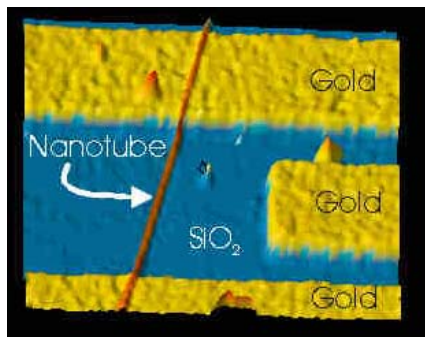
Chemical Catalysis



Magnetic Domains



Piezo-Electric Sensors



Carbon Nanotube

NSLS-II will enable:

- **< 10 nm x-ray nanoprobe**
- **Coherent imaging**
- **Time-resolved Speckle Dynamics**

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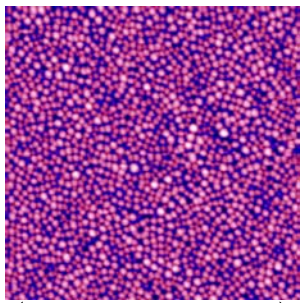
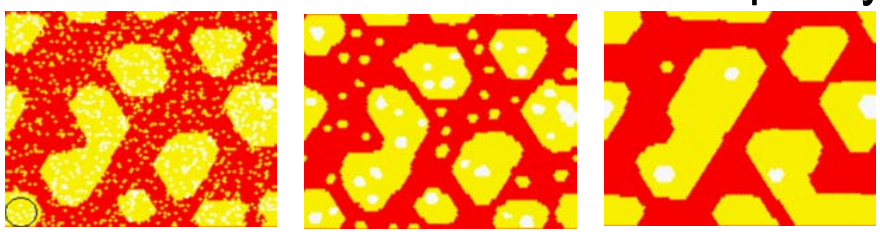
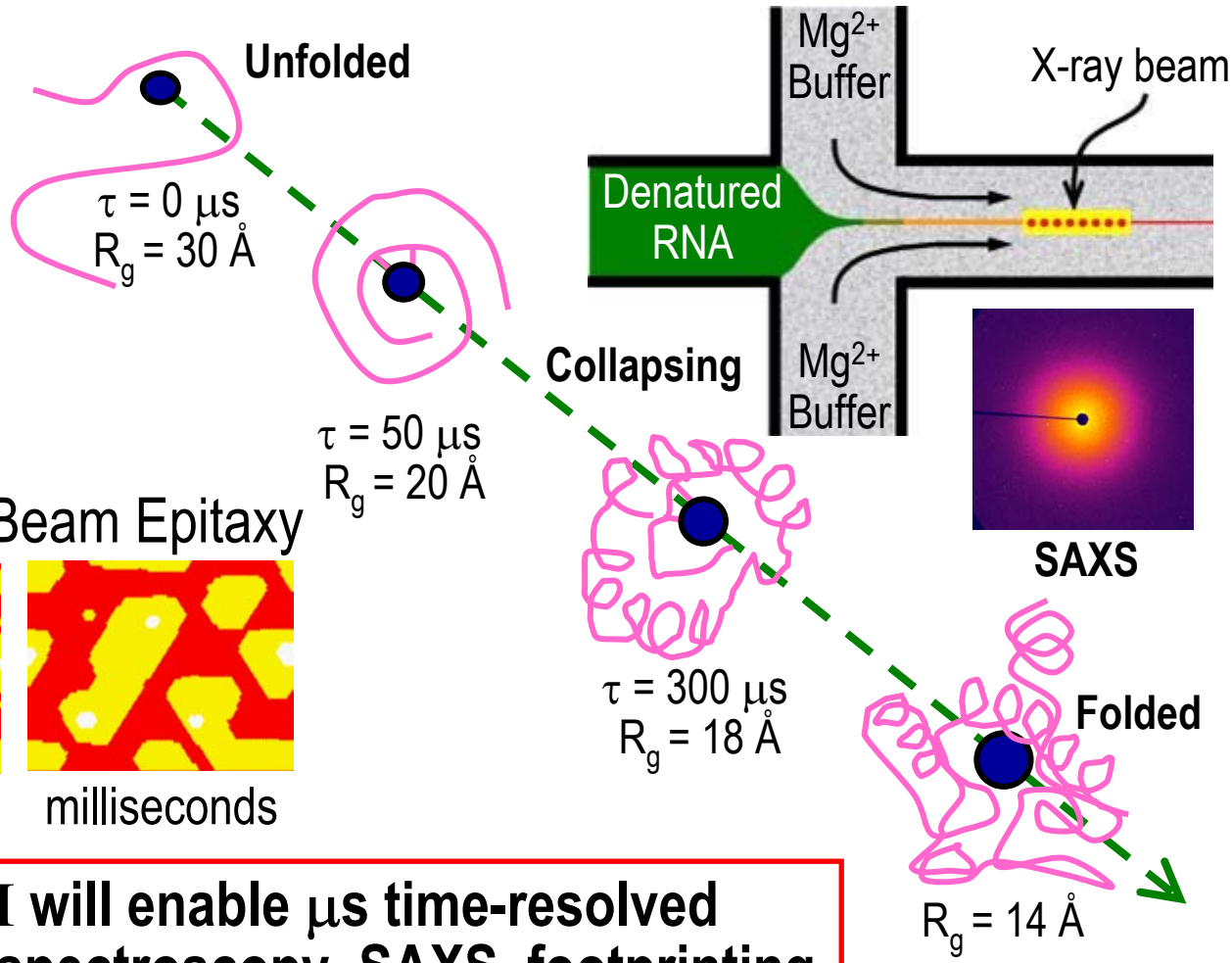
How do Proteins Fold and Materials Grow?

Self Organized Nanoscale Surface Structures



Pulsed Laser Molecular Beam Epitaxy

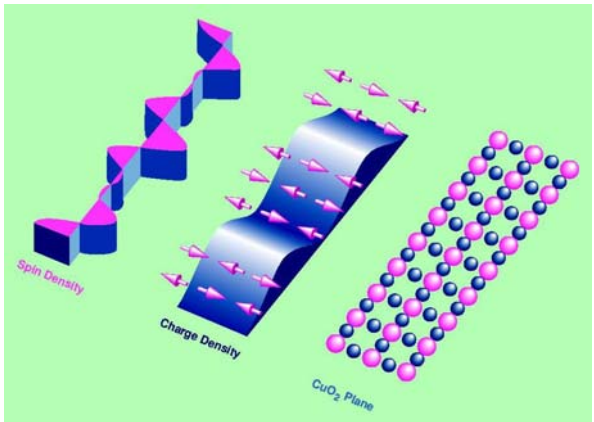




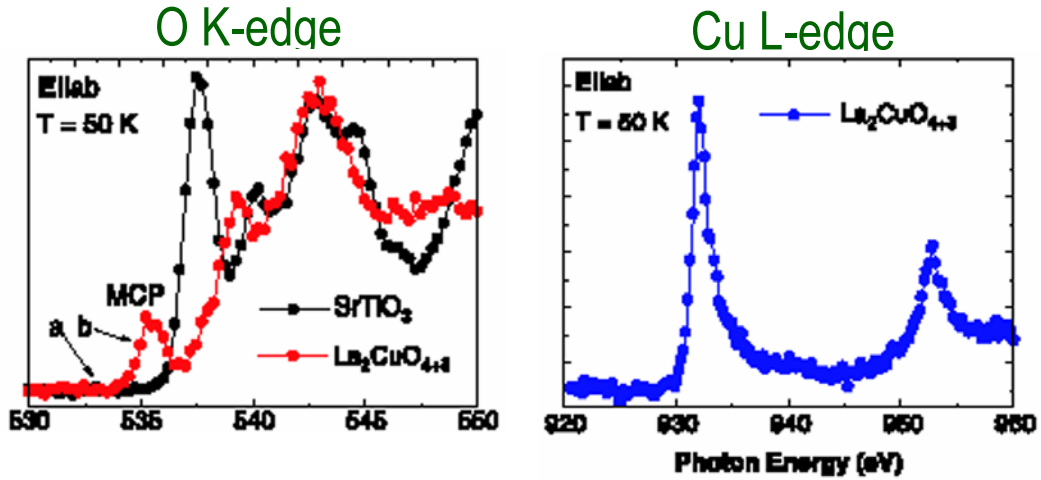
NSLS-II will enable μs time-resolved diffraction, spectroscopy, SAXS, footprinting

What is the Nature of Charge Dynamics in Strongly Correlated Electron Systems?

Resonant x-ray scattering: a direct structural probe of charge carriers by exploiting the large resonant enhancement and selection rules associated with core-level resonances



Charge and spin stripes in complex oxides

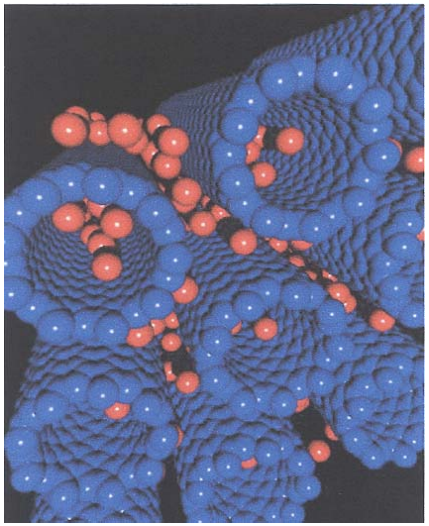


Abbamonte et al, Science (2002)

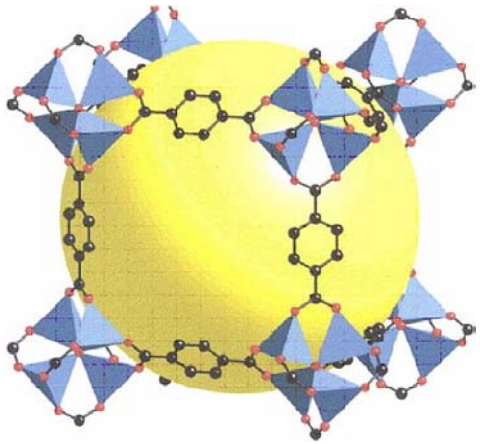
NSLS-II will enable:

- **Inelastic x-ray scattering with ~ 1 - 10 meV resolution**
- **Charge aspects of static stripes**
- **Coherent x-ray imaging of domain structures and studies of dynamics**

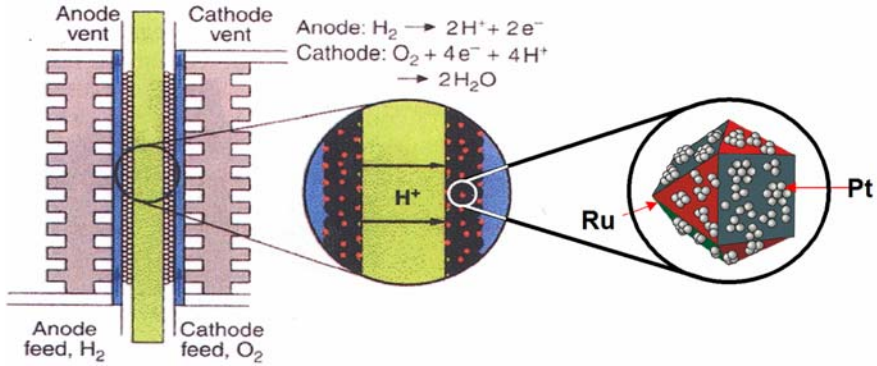
How do we Design Catalyst Structures for Controlled Activity and Selectivity?



Single Wall Nanotubes



Metal-organic Framework Structures



Nanocatalysts, Electrocatalysis, Fuel Cells

Materials for hydrogen storage

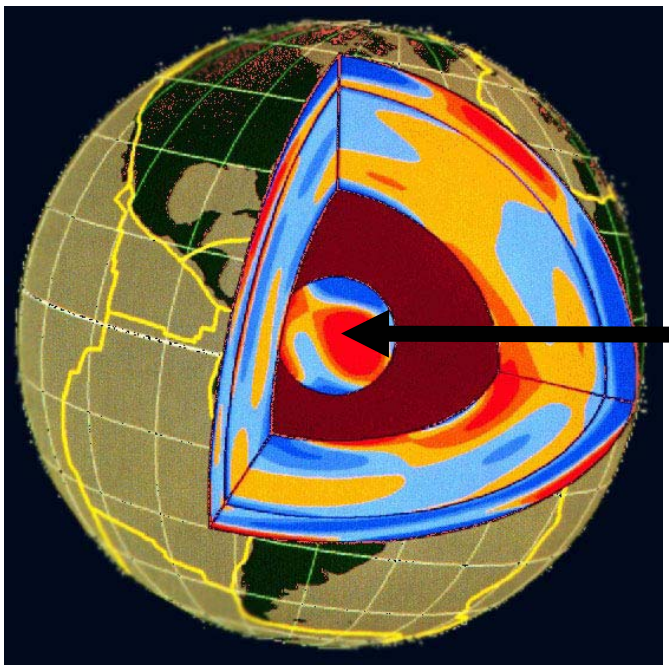
***in situ* characterization of catalytic reactions**

NSLS-II will enable:

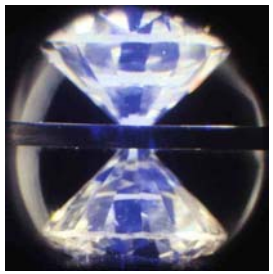
- **Spectromicroscopy with <10 nm resolution**
- **Chemical kinetics on μsec time scales**

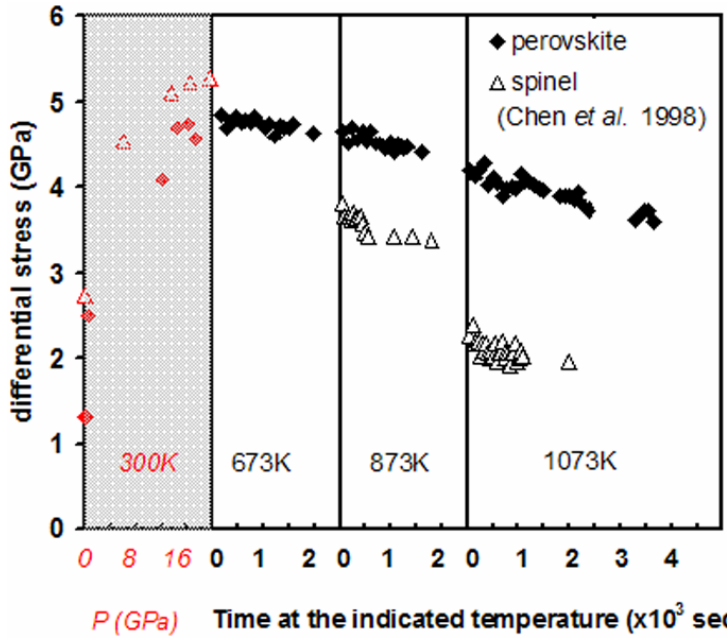
How do Materials Behave under Extreme Conditions?

Higher brightness is essential for studies of smaller samples at higher pressures and temperatures relevant for the Earth's inner core.



Seismic Image of the Earth





Why no earthquakes in the lower mantle?

NSLS-II will enable measurements at higher pressures, temperatures, and magnetic fields, and discovery of new phases and novel materials

NSLS-II Beamlines and Instrumentation

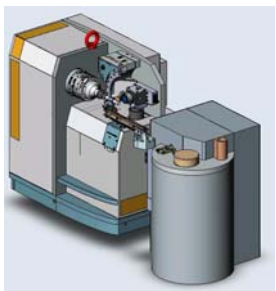
Tentative Insertion Device Beamline Plan

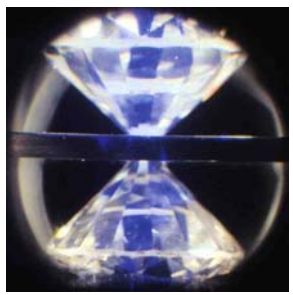
5 Macromolecular Crystallography
1 X-ray Micro-beam diffraction
1 Materials science/time-resolved
1 Resonant/Magnetic x-ray scattering
4 Soft x-ray undulator beamlines

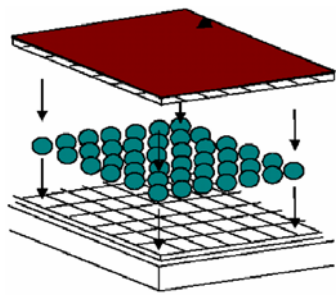
1 Coherent X-ray Scattering
1 Small angle x-ray scattering
1 Inelastic x-ray scattering
2 Superconducting Wiggler (6 beamlines)
4 To be determined

Optimized and Unique Endstation Instrumentation

Automation, Robotics
Ultra-High Pressures
Ultra-High Magnetic Fields
Very Low Temperatures
Advanced, efficient, high thoughput, large area detectors

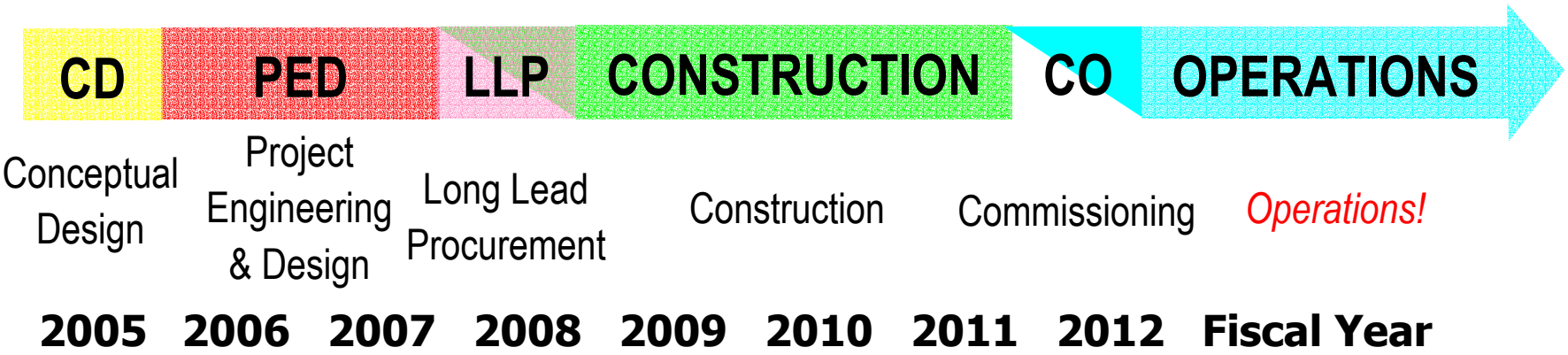






Pixel Array Detector

NSLS-II Preliminary Project Profile



FTE Years: 531

TEC: $393M FY04

TPC: $424M FY04

Office of Science
U.S. DEPARTMENT OF ENERGY

BROOKHAVEN NATIONAL LABORATORY
BROOKHAVEN SCIENCE ASSOCIATES

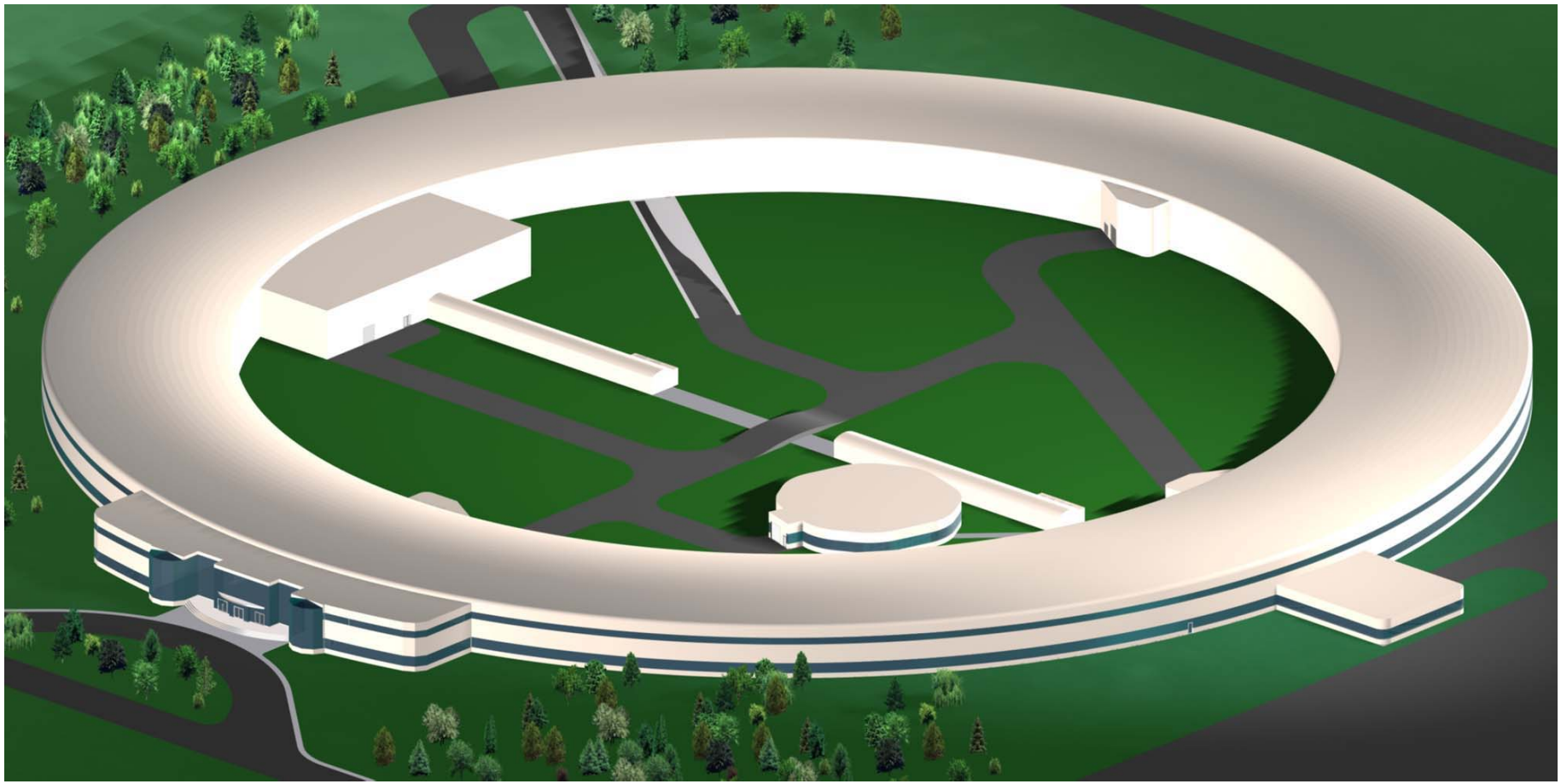
We need your continued input!

Breakout Sessions

- Inelastic X-ray Scattering
- Infrared
- Macromolecular Crystallography
- SAXS/XPCS
- Nanoprobe/Imaging
- Scattering
- Spectroscopy

Please give us your suggestions on NSLS-II design features, beamline characteristics, instrumentation concepts, and other thoughts!

NSLS-II
The Future National Synchrotron Light Source



Enabling "grand challenge" science